Culture Density and Size Effects on Performance to Release of Juvenile Chinook Salmon and Subsequent Ocean Survival. Smolt Releases from Capilano Hatchery in 1980 and 1981

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CULTURE DENSITY AND SIZE EFFECTS ON PERFORMANCE TO RELEASE OF JUVENILE CHINOOK SALMON AND SUBSEQUENT OCEAN SURVIVAL. SMOLT RELEASES FROM CAPILANO HATCHERY IN 1980 AND 1981

by

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ABSTRACT

Fagerlund, U. H. M., J. R. McBride, B. S. Dosanjh, and E. T. Stone. 1987. Culture density and size effects on performance to release of juvenile chinook salmon and subsequent ocean survival. Smolt releases from Capilano Hatchery in 1980 and 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1572: 24 p.

Juvenile chinook salmon (Oncorhynchus tshawytscha), progeny of adults returned to and spawned at Capilano Hatchery in 1979 and 1980 were stocked in ponds at three levels of density for three months prior to release on June 5, 1980 and May 21, 1981, respectively. Maximum density increases were 88 and 121% in the two years. Representative numbers of fish were in both years provided with magnetic, coded, wire nose tags identifying each group. Moreover, in 1981 fish above and below the mean length were given separate codes.

High stocking density was associated with slight, but insignificant decreases in weight and length and an increase in condition factor at release in 1980, but not in 1981. Mortality before release was less than 1% and least at the lowest density. Food conversion efficiency decreased with increasing density in either year.

Body composition at time of release was only weakly affected by density. However, moisture and ash content was negatively correlated and lipid content positively correlated with size of fish.

The effect of density on osmoregulation was not consistent.

Density did not affect interrenal cell nuclear diameters, but plasma cortisol concentrations increased moderately with increasing density.

Total estimated returns (fishery and escapement) was 0.66% and 2.12% of the releases in 1980 and 1981, respectively. Maximum increases in density resulted in 12.7% and 17.1% decreases in return rates from the two releases. There were significant shifts in the contribution from the different year classes. Small juveniles returned at a lower rate than large fish and their return rates were also most affected by density.

Differences in size of returning fish between density groups were small. Neither did size of smolts influence size of 2 and 3 year old fish, but larger smolts returned as larger 4-year-olds.

Results are also provided relating to a group of fish initially reared in artificial light on a natural photoperiod.

Key words: chinook salmon, (Oncorhynchus tshawytscha), density, chemical composition, survival growth

RESUME

Fagerlund, U. H. M., J. R. McBride, B. S. Dosanjh, and E. T. Stone. 1987. Culture density and size effects on performance to release of juvenile chinook salmon and subsequent ocean survival. Smolt releases from Capilano Hatchery in 1980 and 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1572: 24 p.

Des saumons quinnats juvéniles (Oncorhynchus tshawytscha), progéniture d'adultes qui sont revenus à la piscifacture de Capilano et y ont frayé en 1979 et 1980, ont été ensemencés dans des étangs en fonction de trois densités pendant trois mois avant leur lâcher respectif le 5 juin 1980 et le 21 mai 1981. Pour ces deux années, les augmentations maximum de la densité se situaient à 88% et 121%. Chaque année, des échantillons représentatifs de poissons ont été munis d'étiquettes nasales métalliques à code magnétique et en 1981, les poissons dont la longueur se situait au-dessus et au-dessous de la longueur moyenne ont été marqués de codes différents.

En fonction d'une densité élevée à l'ensemencement, on a noté de légères baisses significatives du poids et de la longueur des poissons et une augmentation du coefficient de condition au moment du lâcher en 1980 (mais non en 1981). Le taux de mortalité avant le lâcher était inférieur à 1%; le taux le moins élevé était fonction de la plus faible densité. L'efficacité de conversion de la nourriture a baissé en fonction d'une augmentation de la densité en 1980 et 1981.

Au moment du lâcher, la densité n'avait qu'une faible influence sur les composantes corporelles. Toutefois, la teneur en humidité et en cendres était en corrélation négative avec la taille du poisson tandis que la teneur en lipides était en corrélation positive avec ce facteur.

L'incidence de la densité sur la capacité osmorégulatoire n'était pas uniforme.

La densité n'a pas influé sur le diamètre du noyau des cellules interrénales mais les concentrations de cortisol plasmatique ont modérément augmenté en fonction d'une augmentation de la densité.

Le nombre total estimatif de saumons amontants (pêche et échappée) issus des lâchers de 1980 et 1981 s'élève respectivement à 0,66% et 2,12% du nombre de saumons lâchés en 1980 et 1981. Des augmentations maximum de la densité ont entraîné des baisses respectives de 12,7% et 17,1% des taux de retour des saumons issus des deux lâchers. On a observé des décalages marqués de la contribution des deux classes annuelles. Les petits juvéniles sont remontés à un plus faible taux que les gros poissons; de plus, la densité a eu une plus grande incidence sur le taux de remonte des premiers.

Les différences entre la taille des poissons amontants issus des deux groupes déversés à différentes densités étaient faibles. La taille des saumoneaux n'a pas influé sur la taille des poissons de deux et de trois ans quoique les gros saumoneaux soient revenus à l'état de gros poissons de 4 ans.

On présente aussi des résultats obtenus d'un groupe de poissons gardés en milieu éclairé artificiellement selon une photopériode normale naturelle.

Mots-clés: saumon quinnat, Oncorhynchus tshawytscha, densité, composition chimique, survie, croissance

INTRODUCTION

Population density has been shown to affect both feral fish and fish under cultivation (Schreck 1981). Two separate mechanisms by which density effects may be manifested are of particular significance to cultured fish. First, at both low and high densities social demands, such as the need for space and the establishment of hierarchies influence various aspects of the physiological development. Second, at higher densities the quality of the physical environment deteriorates, i.e., oxygen levels are decreased, ammonia levels are increased and transmission of disease organisms is facilitated and possibly enhanced. Both mechanisms result in stress in the fish, which may adversely affect future performance capacity. A third mechanism, namely the conditions in the ocean environment, also operates to affect the size of fish populations. Although many aspects of the hazards encountered in the ocean are poorly understood, some density-dependent phenomena have been identified. Amongst these may be noted the "swamping" of predators and the competition for food, each influencing ocean survival in opposite directions.

In tests with coho salmon in two British Columbia hatcheries (Sandercock and Stone 1979; Fagerlund et al. 1981, 1983, 1984) increased culture densities have been observed to affect growth rate, body composition, food conversion efficience, interrenal activity and osmo-regulatory capacity of juveniles and return rates of "jacks" and adults. The present report describes our studies of density effects on chinook salmon reared in a cold water hatchery.

MATERIALS AND METHODS

CHINOOK RELEASED IN 1980

Chinook fry of Capilano hatchery stock were reared in troughs at 10.5°C for 6 months after swim-up. During February 21-28 fish were randomly distributed into three Burrows' ponds. Final densities are shown in Table 1. Ponds received water from two sources, river water (5°C) and heated spring water (9°C) introduced at opposite ends of the ponds, resulting in an average temperature of (6°C). Fish were exposed to a natural photoperiod. The fish were fed Oregon Moist Pellets in amounts varying with temperature and size of fish according to the manufaturers recommended feeding schedule (Table 1). The size of fish was determined biweekly, alternating between bulkweighing and weighing of individual fish in random samples (Fagerlund et al. 1983). During the latter part of May about 75000 fish from each pond were fitted with magnetic, coded wire nose tags, each group having a separate code number. Immediately prior to release the ratio of tagged to untagged fish was determined for each group. The total number of fish in the pond was determined from this information. The numbers were at variance with the originally estimated numbers as shown in Table 1.

CHINOOK RELEASED IN 1981

Rearing conditions in 1981 were essentially the same as in 1980. Initially three ponds were loaded at densities similar to those in 1980. However, on April 8 about 40000 fish were moved from each pond to one of three basement settling ponds (1.5 x 10.4 x 0.8 m) supplied with artificial light regulated to conform with the natural light cycle. On May 6 these fish were pooled into one outside holding pond (5.2 x 15.2 x 1.5 m) and identified as the "Photoperiod" group. Although this group is included here with the density groups a comparison on the basis of density is invalid because of the difference in rearing conditions.

In late April and early May two samples of about 40000 fish from each pond, representing fish longer, respectively shorter than the mean length of the group (Table 2) were supplied with nose tags. From the photoperiod group about 75000 fish were tagged. Total number of fish in the ponds were determined as in 1980 and again revealed significant discrepancies from initial counts.

GENERAL COMMENTS

Water flow rates in each pond were initially 20 L/sec rising to 40 L/sec at time of release.

Blood samples for cortisol analysis were collected in micro-haematocrit tubes within 5 min of capture. Analyses were carried out with a radioimmunoassay kit (Gamma Coat, Clinical Assays, Cambridge, Massachusetts). The method does not permit accurate estimation of values between 0 and 10 ng/ml. Since a significant portion of the generated values fall within this range statistical analyses were performed on ranked values. Histological techniques have been described by van Overbeeke and McBride (1971) and methods for proximate analysis of body composition by Higgs et al. (1979).

Condition factors were calculated for individual fish as $W/L^{3.25} \times 1000$, were W is weight in g and L is length in cm.

Data, except those for cortisol, were analyzed by ANOVAs followed by Duncan's or Tukey's multiple range test ($\P = 0.05$). Values in tables carrying a common letter are not significantly different.

In 1980 some analyses were carried out on samples representing small, medium and large fish. These fish were chosen from fish with lengths falling within the ranges of lengths of equal-numbered sub-populations of short, medium and long fish in a random sample of 200 fish. In 1981 samples were only taken from two size groups, namely those shorter or longer than the average length for each group.

RESULTS

GROWTH OF JUVENILES

Fish raised at the lowest density in 1980 weighed 7.4 % more than those at the highest density at the time of release (Table 3). Length was also significantly greater at lower densities. In 1981, however, there were no significant differences in either weight or length between groups at time of release (Table 4). Release weights in 1981 were more than two grams larger than weights at the same time of the year in 1980.

Condition factors in both years decreased with age of the fish. At time of release condition factors of low-density fish were slightly, but significantly, lower than in other groups in 1980, but differences were not significant in 1981. When size was included in the analysis in 1981, longer fish had lower condition factors. Since smolting is commonly associated with a decrease in this parameter, the results suggest, as in the case of coho (Fagerlund et al. 1983), that larger fish had a greater sea-water readiness. An analysis of linear regression of condition factor on length in 1980 and also in 1981 (not shown in tables) corroborated these findings (Table 5).

An analysis of skewness in 1980 showed a trend to decreasing positive values for weights, but increasing negative values for length as density increased. However, the differences were not statistically significant. Skewness in weight increased with time to positive values, while that of length showed a decreasing trend in negative values. In 1981 (not shown) as in 1980 differences in skewness were not statistically significant.

MORTALITY, FOOD CONSUMPTION AND FOOD CONVERSION IN JUVENILES

Observed mortality of juveniles (Table 1) was below 1 percent of initial loading numbers in either year and least at the lowest density.

Food consumption per fish and food conversion efficiency were both weakly affected by density. Food consumption did not show a consistent trend in 1980, but decreased with increasing density in 1981. Food conversion efficiency was markedly increased at the highest density in 1980, but was unaffected by density in 1981.

BODY COMPOSITION OF JUVENILES

Ponding density generally had minor influences on body composition (Tables 7, 8, 9), with the exception of April 1980 samples and the Photoperiod group in 1981. This was in contrast to observations with coho (Fagerlund et

al. 1983, 1984). In the April samples increasing density was associated with decreasing moisture content, while protein and lipid content increased with the exception of "dry protein" which showed the opposite trend. The Photoperiod group, reared at a density similar to that of the low density group, had the lowest moisture and "dry protein" and the highest lipid content in 1981.

When comparing the three sampling times the effect of size on body composition was consistent. Moisture and ash content was negatively correlated and lipid content was positively correlated with size of fish. However, size did not generally have a significant effect on "wet protein", but "dry protein" decreased with increasing size of fish. These results generally conform to trends observed in the previous coho trials.

SALT WATER CHALLENGE TESTS

Plasma sodium concentrations (Table 10) in juvenile chinook held in seawater for 24 hours in early May, 1980 showed that fish in all groups had acceptable osmoregulatory capacity.

In 1981 fish were challenged on three occasions. On April 16 fish raised both at the lowest and the highest density regulated plasma sodium concentrations poorly, while fish at the medium density had significantly lower sodium levels. At this time, in contrast to all other sampling occasions, small fish had higher sodium levels than large fish. Since considerable differences existed between mean weights of the groups, the differences in sodium values may at least partly be explained by the differences in weight. On May 11, all groups maintained normal plasma sodium concentrations. On May 29, eight days after the bulk of the fish had been released, fish raised at the two lowest densities (density 1 and Photoperiod groups) regulated sodium well, while levels were significantly higher in fish raised at the two highest densities. There were no mortalities in any of the tests.

STRESS ASSESSMENT

In order to demonstrate potential differences in stress levels between groups, interrenal cell nuclear diameters (ICND) and plasma cortisol concentrations were determined. Changes in ICNDs were minor (Table 11). There was a trend to increasing cortisol concentrations at higher densities in 1980 (Table 12). This was particularly evident in small fish. The results suggest a minor increase in stress at higher densities. To assess the importance of this increase for the wellbeing of the fish is difficult. However, stress is known to reduce the immune competence of fish (Manning and Mughal 1985) resulting in increased susceptibility to infection. Evidence for this was found in coho salmon (Fagerlund et al. 1984) in which ponding density and mortality were positively correlated.

RETURNS OF 'JIMMIES','JACKS' AND ADULTS

The combined return to the fishery and escapement to the hatchery of all age groups was 0.66% of the 1980 release and 2.12% of the 1981 release. The overwhelming majority of fish returned as 2 and 3 year old. Less than 10% of returns were 4 year old. A few precocious males returned to the hatchery in the fall of the release year (1 year old) and a few were caught as 5 year old in the sport fishery.

Effects of density - Maximum increases in density in 1980 and 1981 were 88 and 121%, respectively. These resulted in decreases of 12.7 and 17.1% in total returns originating from the two release years (Tables 13, 14). A breakdown of returns into age groups shows, that - among fish released in 1980 - 1-year-olds were mainly from the low density group while all densities were represented in the following year. The largest decreases occurred in 2-year-olds, namely 25.1 and 22.0% in the two years. A small number of 5-year-olds were found originating from both years' releases.

Density did not have a consistent effect on total returns to the hatchery (Table 15). However, there was a shift in the relative proportion of numbers of large fish returning as 2- and 3-year-olds, namely a marked increase in the former and a decrease in the latter with increasing density. In escapements to the hatchery males represented the major portion. There was a trend to decreased relative numbers of females with increasing density, namely from 27.2 to 6.7% in returns from the 1980 release and from 22.8 to 15.5% from the 1981 release.

Effect of size - In 1981 small juveniles returned at a lower rate than large juveniles, comprising 38.2% of total recoveries at the lowest density and decreasing to 33.3% at the highest density. The density increase caused a decrease of only 10.4% in returns from large smolts, but a decrease of 27.9% in that of small smolts. Returning "jimmies" originated entirely from large smolts.

Size of smolt had an even greater effect on returns to the hatchery. Accordingly, only 25.8% of returning fish originated from small smolts. There was a strong interaction of density and age group in fish originating from large smolts. Thus returns of 2-year-olds increased by 105.1% over the maximum density increase, while returns of 3-year-olds decreased by 36.6%.

Photoperiod group - Fish raised initially under an artificial photoperiod, despite being held at a density similar to that of the low density group, had the lowest return rates. This was true regardless of mode of capture.

SIZE OF RETURNING FISH

Average sizes of returning 2,3 and 4 year old fish originating from the 1980 release were slightly smaller than those from the 1981 release.

Differences in size between density groups were small and did not suggest a trend, except in the small number of 4 year old fish from the 1980 release, which showed a gradual decrease in size with increasing density (returns to the commercial fishery, Table 16). Numbers of observations from hatchery returns were too small to establish a reliable trend.

Size of smolt did not influence size of returning 2 and 3 year old fish. However, when 4 year old fish were examined large smolts returned consistently as larger adults, regardless of density.

The size of fish in the Photoperiod group were not appreciably different from that of the other groups.

COMMENTS

Small chinook within a pond had lower body lipid content and higher moisture content than large fish at any time point. However, this was not exclusively an effect of size, since the increase in size between April 28 and May 21, 1980 in every size group resulted in opposite trends, namely decreases in lipid and increases in moisture content. There is a large body of literature which shows that the stress associated with social interaction in animal populations, including those of fish (Schreck 1981), affects small members more than large. One manifestation is a lower lipid content in small fish. Thus, the differences in body composition between small, medium and large fish observed here may reflect a difference in stress levels between size groups. It can be expected, that stress level affects the performance capacity of the fish. Accordingly, although increasing the density reduced the overall return rate, that of small smolts was affected more than that of large fish.

Results obtained by Bilton (1984) and data reported here show a positive relationship between chinook smolt size within hatchery populations and adult return rate. However, considerations noted above suggest that, in addition to size *per se*, the relative size within a hatchery population may be of importance for survival. This should be confirmed in studies in which groups of fish raised to various sizes independently of each other are compared to similar-sized fish forming parts of a population.

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TABLE 1. Number of fish and performance data for experimental groups of juvenile chinook salmon in 1980 and 1981.

	Density 1	2	3	Photoperiod
1979 brood. Released June 5, 1980				
No. of fish released	212713	340435	398940	
Discrepancy loss (-), gain (+)*	- 8974	+ 5386	- 44905	
Mortalities (% of initial density, 25/2 - 5/6)	0.55	0.68	0.62	
Food consumption (g/fish) 12/3 - 5/6	5.33	4.87	5.45	
Food conversion efficiency (g gain/g food) 12/3 - 5/6	0.74	0.74	0.60	
1980 brood. Released May 21, 1981				
No. of fish released	171219	272310	378422	103687
Discrepancy loss*	-12639	-29556	-38363	-13520
Mortalities (% of initial density, 25/2 - 21/5)	0.37	0.48	0.45	0.16**
Food consumption (g/fish) 20/3 - 21/5	6.36	6.24	5.95	4.07**
Food conversion efficiency 20/3 - 21/5	0.72	0.69	0.74	0.68**

* determined 5/6/1980 and 21/4/81 by calculating ratio of tagged to untagged fish.

** 10/4 - 21/5

TABLE 2. Tag codes, weights, lengths and condition factors of juvenile chinook at time of release. Body measurements were determined on fish shorter (small) or longer (large) than the mean for a group.

Year	Tag code	Density	Size group	Weight (g)		Length (cm)		Condition factor	
				X	SD	X	SD	X	SD
1980									
	2-18-32	1	All fish	6.11	1.49	8.51	0.68	5.68	0.33
	2-18-31	2	All fish	5.98	1.44	8.40	0.66	5.81	0.35
	2-18-30	3	All fish	5.69	1.53	8.24	0.72	5.88	0.36
1981									
	2-21-51	1	Small	6.52	1.03	8.60	0.42	5.94	0.45
	2-21-50		Large	8.84	1.27	9.54	0.38	5.78	0.44
	2-21-53	2	Small	6.52	0.95	8.61	0.37	5.93	0.42
	2-21-52		Large	8.92	1.19	9.54	0.35	5.82	0.37
	2-19-40	3	Small	6.29	1.03	8.52	0.42	5.90	0.52
	2-19-41		Large	8.72	1.13	9.50	0.35	5.77	0.34
	2-17-35	Photoperiod	Small	6.42	1.12	8.47	0.47	6.13	0.57
	2-17-35		Large	8.84	1.09	9.46	0.34	5.92	0.32

TABLE 3. Weights, lengths and condition factors of juvenile chinook raised at Capilano Hatchery in 1980. Sample size was 200.

	Density 1	2	3	All densities
Weight				
March 12	2.17[a*]	2.36[a]	2.40[a]	2.31[a]
April 23	4.47[b]	4.42[b]	4.43[b]	4.44[b]
May 21	5.82[de]	5.23[c]	5.42[c]	5.47[c]
May 30	6.11[f]	5.98[ef]	5.69[d]	5.93[d]
SEM		0.09		0.05
Length				
March 12	5.84[a]	6.02[b]	6.03[b]	5.96[a]
April 23	7.35[c]	7.35[c]	7.35[c]	7.35[b]
May 21	8.21[e]	8.12[de]	8.07[d]	8.12[c]
May 30	8.51[f]	8.40[f]	8.24[e]	8.38[d]
SEM		0.05		0.03
Condition factor				
March 12	6.77[f]	6.74[ef]	6.77[f]	6.75[d]
April 23	6.64[de]	6.61[d]	6.60[d]	6.61[c]
May 21	6.11[c]	5.71[a]	6.00[c]	5.95[b]
May 30	5.68[a]	5.81[b]	5.88[b]	5.80[a]
SEM		0.04		0.02

* Duncan's multiple range test. In this and following tables, values carrying a common letter are not significantly different ($\alpha = 0.05$).
Two-way ANOVAs showed significant affect of the following variables:

Parameter	Variable
Weight	density, time, density x time
Length	time, density x time
Condition factor	density, time, density x time

When size (3 size-groups, defined by length) was included as a variable in the ANOVA size had a significant effect on conditon factor. However, differences between size-groups in condition factor were not significant at the individual time points, although condition factors always were inversely correlated with size.

TABLE 4. Weights, lengths and condition factors of juvenile chinook raised at Capilano Hatchery in 1981. Sample size was 300.

	Density 1	2	3	Photoperiod	All groups
Weight					
March 20	3.21[a]*	3.20[a]	3.24[a]	-	3.22[a]
April 10	4.92[c]	4.88[c]	4.62[b]	-	4.81[b]
April 30	6.41[e]	6.73[f]	6.02[d]	6.10[d]	6.32[c]
May 20	7.76[gh]	7.83[h]	7.62[gh]	7.57[g]	7.70[d]
SEM		0.07			0.04
All times	5.58[b]	5.66[b]	5.38[a]	6.84[a]	
SEM		0.04		0.06	
Length					
March 20	6.67[a]	6.70[a]	6.65[a]	-	6.67[a]
April 10	7.53[b]	7.55[b]	7.47[b]	-	7.52[b]
April 30	8.29[e]	8.44[f]	8.19[d]	8.06[c]	8.24[c]
May 20	9.10[h]	9.12[h]	9.06[h]	8.94[g]	9.06[d]
SEM		0.03			0.02
All times	7.90[c]	7.95[d]	7.84[b]	8.50[a]	
SEM		0.02			
Condition factor					
March 20	6.63[e]	6.50[d]	6.72[f]	-	6.62[c]
April 10	6.88[g]	6.75[f]	6.58[de]	-	6.74[d]
April 30	6.54[de]	6.51[cd]	6.40[c]	6.84[gh]	6.57[b]
May 20	5.85[a]	5.87[a]	5.83[a]	6.03[b]	5.90[a]
SEM		0.03			0.02
All times	6.47[b]	6.41[a]	6.38[a]	6.44[c]	
SEM		0.02			

* Duncan's multiple range test.

Two-way ANOVAs showed significant effect of the following variables

Parameter	Variable
Weight	density, time, density x time
Length	time, density x time
Condition factor	density, time, density x time

An ANOVA on condition factors at time of release performed with size (2 equal-sized groups) and density as variables showed that large fish had significantly lower conditon factors than small fish. However, the interaction of density with size was not statistically significant.

TABLE 5. Linear regression of condition factor on length of juvenile chinook released in 1980. Values are covariate slopes, standard errors (SE) and numbers of observations (N). For method of sample selection refer to Materials and Methods.

Time	Slope	SE	N
March 12	- 0.024[a]	0.003	594
April 23	- 0.011[b]	0.003	810
May 21	- 0.017[ab]	0.003	805
May 30	- 0.013[ab]	0.003	596

* Bonferroni's test, $\alpha = 0.05$. A three factor analysis (density, time, length) of covariance performed as a two-way analysis on both means and covariate slopes showed significant effects on slopes of time. The effect of density was not significant at $\alpha = 0.7$. Values carrying a common letter are not significantly different.

TABLE 6. Skewness (g, Snedecor and Cochran 1971) in weight and length in samples of 200 chinook raised in 1980. Values are means and SD of three densities (pooled sampling times) or four sampling times (pooled densities).

	Density		
	1	2	3
Weight	0.222	0.150	0.084
SD	0.245	0.201	0.166
Length	- 0.354	- 0.391	- 0.537
SD	0.321	0.367	0.243

	Time			
	March 12	April 23	May 21	May 30
Weight	- 0.045	0.096	0.334	0.224
SD	0.055	0.208	0.194	0.0736
Length	- 0.746[a*]	- 0.601[b]	- 0.136[b]	- 0.225[b]
SD	0.427	0.238	0.256	0.132

* Duncan's multiple range test.
Two-way ANOVA (time, density) indicated significant differences only for length when compared across times.

TABLE 7. Body composition (% wet weight) of juvenile chinook salmon taken April 28, 1980, from Capilano Hatchery. Values are means and standard errors of the mean (SEM) or standard deviation (SD) of three samples, each containing five fish. Some data showing dry weight composition are provided.

	Density 1	Density 2	Density 3	All densities	
Moisture					
Small	77.64^{c*}	77.97^{c}	76.26^{bc}	77.29^{c}	
Medium	77.21^{c}	76.14^{bc}	74.52^{ab}	75.95^{b}	
Large	76.75^{c}	73.84^{a}	74.29^{ab}	74.96^{a}	
SEM		0.43		0.25	
All sizes	77.20^{c}	75.98^{b}	75.02^{a}	76.07	
SEM		0.25		1.58 (SD)	
Protein					Dry protein
Small	16.87	16.59	17.29	16.92	74.53^{c}
Medium	16.55	17.30	17.17	17.00	70.84^{b}
Large	16.01	17.32	17.18	16.84	67.31^{a}
SEM		0.31		0.18	0.39
All sizes	16.48^{a}	17.07^{ab}	17.21^{b}	16.92	
SEM		0.18		0.62 (SD)	
Dry protein	72.31^{b}	71.38^{b}	69.03^{a}		70.89
SEM		0.39			3.60 (SD)
Lipid					Dry lipid
Small	3.62^{a}	3.94^{a}	4.50^{b}	4.02^{a}	17.69^{a}
Medium	4.78^{b}	4.70^{b}	5.91^{c}	5.13^{b}	21.29^{b}
Large	5.86^{c}	6.85^{d}	6.55^{d}	6.42^{c}	25.61^{c}
SEM		0.18		0.11	0.35
All sizes	4.75^{a}	5.17^{b}	5.65^{c}	5.19	
SEM		0.11		0.13 (SD)	
Dry lipid	20.80^{a}	21.27^{ab}	22.53^{b}		21.53
SEM		0.35			3.58 (SD)
Ash					Dry ash
Small	2.42	2.19	2.34	2.32^{b}	10.20^{b}
Medium	2.21	2.35	2.31	2.29^{b}	9.53^{b}
Large	2.08	2.17	2.15	2.13^{a}	8.53^{a}
SEM		0.09		0.05	0.19
All sizes	2.24	2.23	2.27	2.25	
SEM		0.05		0.17 (SD)	
Dry ash	9.81^{b}	9.34^{ab}	9.10^{a}		9.42
SEM		0.19			0.91 (SD)

* Tukey's test. Two-way ANOVAs showed significant effects of the following variables ($\alpha = 0.05$).

Body constituent	Variable
Moisture	density, size, density x size
Protein	density
Dry protein	density, size, density x size
Lipid	density, size, density x size
Dry lipid	density, size, density x size
Ash	size
Dry ash	density, size

TABLE 8. Body composition (% wet weight) of juvenile chinook salmon taken May 21, 1980, from Capilano Hatchery. Values are means and standard errors of the mean (SEM) or standard deviation (SD). Samples containing fifteen fish were ground up and analyzed in triplicate. Some data showing dry weight composition are provided.

	Density 1	2	3	All densities	
Moisture					
Small	79.42^{d}	80.32^{e}	79.66^{d}	79.80^{c}	
Medium	78.02^{b}	78.77^{c}	78.23^{b}	78.34^{b}	
Large	77.83^{b}	77.36^{a}	77.25^{a}	77.48^{a}	
SEM		0.09		0.06	
All sizes	78.42^{a}	78.82^{b}	78.38^{a}	78.54	
SEM		0.06		1.04 (SD)	
Protein					
Small	15.62	15.81	15.42	15.62^{a}	77.34^{c}
Medium	16.18	16.26	15.70	16.05^{b}	74.10^{b}
Large	15.92	16.18	16.10	16.07^{b}	71.35^{a}
SEM		0.11		0.07	0.29
All sizes	15.91^{ab}	16.08^{b}	15.74^{a}	15.91	
SEM		0.07		0.33 (SD)	
Dry protein	73.78^{a}	76.13^{b}	72.89^{a}		74.27
SEM		0.29			3.09 (SD)
Lipid					
Small	3.33^{bc}	2.51^{a}	3.08^{b}	2.97^{a}	14.70^{a}
Medium	4.03^{d}	3.53^{c}	4.20^{d}	3.92^{b}	18.08^{b}
Large	4.55^{e}	4.69^{e}	5.03^{f}	4.75^{c}	21.11^{c}
SEM		0.05		0.03	0.14
All sizes	3.97^{b}	3.57^{a}	4.10^{c}	3.88	
SEM		0.03		0.80 (SD)	
Dry lipid	18.34^{b}	16.69^{a}	18.85^{c}		17.96
SEM		0.14			2.93 (SD)
Ash					
Small	2.16	2.30	2.19	2.22	10.99^{c}
Medium	2.12	2.24	2.17	2.17	10.04^{b}
Large	2.05	2.17	2.06	2.09	9.29^{a}
SEM				0.04	0.18
All sizes	2.11	2.23	2.14	2.16	
SEM		0.04		0.12 (SD)	
Dry ash	9.80^{a}	10.59^{b}	9.93^{ab}		10.11
SEM		0.18			0.93 (SD)

* Tukey's test. Two-way ANOVAs showed significant effects of the following variables ($\alpha = 0.05$).

Body constituent	Variable
Moisture	density, size, density x size
Protein	density, size
Dry protein	density, size, density x size
Lipid	density, size, density x size
Dry lipid	density, size, density x size
Ash	nil
Dry ash	density, size

TABLE 9. Body composition (% wet weight) of juvenile chinook salmon taken May 21, 1981, from Capilano Hatchery. Values are means and standard errors of the mean (SEM) or standard deviation (SD) of ten samples, each containing three fish. Some data showing dry weight composition are provided.

	Density 1	Density 2	Density 3	Photoperiod	All densities	
Moisture						
Small	77.64^{d}	76.30^{c}	77.06^{d}	75.36^{ab}	76.77^{b}	
Large	76.22^{bc}	75.85^{bc}	75.41^{ab}	74.78^{a}	75.68^{a}	
SEM	0.17	0.17	0.17	0.24	0.09	
All sizes	76.93^{c}	76.07^{b}	76.23^{b}	75.07^{a}	76.22	
SEM	0.12	0.12	0.12	0.17	0.99 (SD)	
Protein						Dry protein
Small	15.75	16.19	15.95	15.89	15.95	68.72^{b}
Large	15.73	16.24	15.98	16.27	16.02	65.89^{a}
SEM	0.21	0.21	0.21	0.29	0.11	0.42
All sizes	15.74	16.22	15.96	16.08	15.99	
SEM	0.15	0.15	0.15	0.21	0.65 (SD)	
Dry protein	68.29^{b}	67.78^{b}	67.25^{b}	64.50^{a}		69.31
SEM	0.56	0.56	0.56	0.78		3.15 (SD)
Lipid						
Small	4.39	4.72	4.56	5.24	4.66^{a}	20.01^{a}
Large	5.66	5.57	5.98	6.52	5.85^{b}	24.03^{b}
SEM	0.15	0.15	0.15	0.22	0.08	0.32
All sizes	5.03^{a}	5.15^{a}	5.27^{a}	5.88^{b}	5.25	
SEM	0.11	0.11	0.11	0.15	0.81 (SD)	
Dry lipid	21.68^{ab}	21.49^{a}	22.10^{ab}	23.57^{b}		22.02
SEM	0.42	0.42	0.42	0.60		2.80 (SD)
Ash						
Small	2.28	2.45	2.33	2.48	2.37^{b}	10.22^{b}
Large	2.13	2.07	2.18	2.25	2.14^{a}	8.82^{a}
SEM	0.06	0.06	0.06	0.08	0.03	0.15
All sizes	2.20	2.26	2.26	2.37	2.26	
SEM	0.04	0.04	0.04	0.06	0.23 (SD)	
Dry ash	9.58	9.46	9.52	9.51		9.51
SEM	0.20	0.20	0.02	0.28		1.10 (SD)

* Tukey's test. Two-way ANOVAs showed significant effects of the following variables ($\alpha = 0.05$).

Body constituent	Variable
Moisture	density, size, density x size
Protein	nil
Dry protein	density, size, density x size
Lipid	density, size
Dry lipid	density, size
Ash	size
Dry ash	size

TABLE 10. Plasma sodium concentrations (mM/L) in juvenile cinook held for 24 h in sea water. Sample size was 17-18 fish. Small and large fish were those having weights below or above the mean of all fish sampled at each time point.

Date		Density 1	2	3	Photoperiod	Small fish	Large fish
1980							
May 5	X	168.4	168.0	171.1		170.8	167.1
	SD	7.1	4.7	5.2		6.1	5.0
1981							
April 16	X	181.9[b]*	166.6[a]	188.3[b]		183.0	174.3
	SD	11.9	3.6	7.9		12.0	11.6
May 11	X	169.2[a]	172.7[a]	171.2[a]	170.5[a]	170.1	171.7
	SD	6.5	5.9	4.4	5.0	5.3	5.7
May 29	X	171.2[a]	183.4[b]	180.3[b]	172.5[a]	177.5	176.6
	SD	9.7	6.8	5.1	8.8	7.9	10.1

* Tukey's test. One-way ANOVA indicated a pond effect only on April 16 and May 29, 1981.

Mean and SD of weights on April 16 were 4.65 ± 0.77, 4.93 ± 0.65 and 3.96 ± 1.02 in group 1, 2 and 3, respectively.

TABLE 11. Interrenal cell nuclear diameters (μm) in chinook juveniles raised in 1980 and 1981. Values are means and standard errors of the mean (SEM) or standard deviation (SD) of 25 measurements taken on each of three - six fish (April 1980), ten fish (May 1980) or twenty fish (May 1981).

	Density 1	2	3	4	All densities
April 28, 1980					
Small	6.01	5.98	6.09		6.02
Medium	6.07	6.08	5.86		6.00
Large	5.88	6.06	6.04		6.00
SEM		0.03			0.02
All sizes	6.00	6.04	5.99		6.01
SEM		0.02			0.39 (SD)
May 21, 1980					
Small	5.89^{a*}	6.04ab	5.91^{a}		5.95^{a}
Medium	6.07ab	6.02ab	5.90^{a}		6.00^{ab}
Large	5.96ab	6.10b	6.10^{b}		6.05^{b}
SEM		0.02			0.01
All sizes	5.98^{ab}	6.05^{b}	5.97^{a}		6.00
SEM		0.01			0.36 (SD)
May 21, 1981					
Small	5.81	5.88	5.81	5.79	5.83
Large	5.88	5.73	5.72	5.77	5.78
SEM		0.02			0.01
All sizes	5.85	5.81	5.77	5.78	5.80
SEM		0.02			0.45 (SD)

* Tukey's test.
Three-way ANOVAs (density, size, fish) showed significant effects of the following variables ($\alpha = 0.05$).

Time	Variable
April 1980	no significant differences
May 1980	density, size, density x size, fish
May 1981	fish

TABLE 12. Ranking of plasma cortisol concentrations (ng/ml) of juvenile chinook salmon sampled before release in 1981. Values are means of 10 fish. Standard error of means was 5.32.

S group	Density 1	2	3
Small	18.1	54.7	62.5
Large	48.4	30.1	56.8

Kruskal-Wallis one-way analyses of variance performed on all 6 values showed significant effect of density, but not of size. A Bonferroni multiple comparison of densities showed significant differences between pairs as follows (s = significant at $\alpha = 0.05$; N - not significant):

	Size of fish Small	Large
Low vs medium	S	S
Medium vs high	N	S
Low vs hig	S	N

TABLE 13. Capture (no. pr 100,000 fish released) of chinook salmon originating from juveniles released from Capilano Hatchery in 1980.

Density	Age at return	Canadian			US* Total	Can. + US total	Escapement	Total recovery	Mean of all densities
		Sport	Commercial	Total					
1	1	0	0	0	0	0	5	5	
	2	177	87	264	15	279	44	323	
	3	93	178	271	19	290	46	336	
	4	20	20	40	0	40	8	48	
	5	4	0	4	NA	4	0	4	
Total		294	285	579	34	613	103	716	
2	1	0	0	0	0	0	1	1	
	2	99	126	225	21	246	33	279	
	3	91	162	253	52	305	19	324	
	4	12	11	23	0	23	5	28	
	5	0	0	0	NA	0	0	0	
Total		202	299	501	73	574	58	632	
3	1	0	0	0	0	0	0	0	2.0
	2	103	89	192	6	198	44	242	281.3
	3	78	203	281	33	314	23	337	332.3
	4	12	23	35	3	38	8	46	40.7
	5	0	0	0	NA	0	0	0	1.3
Total		193	315	508	42	550	75	625	657.6
Mean of total all densities		229.7	299.7	529.3	49.7	579.0	78.7	657.7	

* Alaska returns.

TABLE 14. Capture (no. pr 100,000 fish released) of chinook salmon originating from juveniles released from Capilano Hatchery in 1981.

Density	Size	Age at return	Canadian			US Total	Can. + US Total	Escapement	Total recovery	Mean of "small" and "large"
			Sport	Commercial	Total					
1	Small	1	0	0	0	0	0	0	0	
		2	282	439	721	9	730	34	764	
		3	248	581	829	6	835	60	895	
		4	94	14	108	0	108	14	122	
	Total		624	1034	1658	15	1673	108	1781	
	Large	1	0	0	0	0	0	37	37	18.5
		2	497	532	1029	190	1219	59	1278	1021.0
		3	441	711	1152	0	1152	131	1283	1089.0
		4	88	147	235	0	235	43	278	200.0
		5	3	0	3	0	3	0	3	1.5
	Total		1029	1390	2419	190	2609	270	2879	2330.0
Mean of total small and large			826.5	1212.0	2038.5	102.5	2141.0	189.0	2330	
2	Small	1	0	0	0	0	0	0	0	
		2	241	284	525	40	565	23	588	
		3	267	252	519	3	522	46	568	
		4	69	92	161	0	161	29	190	
	Total		577	628	1205	43	1248	98	1346	
	Large	1	0	0	0	0	0	56	56	28.0
		2	584	579	1163	31	1194	109	1303	945.5
		3	451	718	1169	14	1183	120	1303	935.5
		4	67	125	192	0	192	36	228	209.0
	Total		1202	1422	2524	45	2569	321	2890	2118.0

Table 14 (con't)

Density	Size	Age at return	Canadian			US	Can. + US	Escapement	Total	Mean of "small"
			Sport	Commercial	Total	Total	Total		recovery	and "large"
Mean of total small and large			889.5	1025.0	1864.5	44.5	1908.5	209.5	2118.0	
3	Small	1	0	0	0	0	0	0	0	
		2	161	373	534	8	542	13	555	
		3	298	233	531	5	536	57	593	
		4	48	62	110	0	110	27	137	
		5	0	0	0	0	0	3	3	
	Total		507	668	1175	13	1188	100	1288	
	Large	1	0	0	0	0	0	29	29	14.5
		2	342	544	885	31	916	121	1037	796.0
		3	555	650	1206	0	1206	83	1289	941.0
		4	93	71	164	0	164	45	209	173.0
		5	12	0	12	0	12	0	12	7.5
	Total		1002	1265	2267	31	2298	278	2576	1932.0
Mean of total small and large			754.5	966.5	1721.0	22.0	1743.0	189.0	1932.0	
Photoperiod		1	0	0	0	0	0	14	14	
		2	238	404	642	47	689	79	768	
		3	307	495	802	5	807	77	884	
		4	44	90	134	0	134	38	172	
		5	7	0	7	0	7	0	7	
	Total		596	989	1585	52	1637	208	1845	

TABLE 15. Escapement to Capilano Hatchery (no. per 100,000 fish released) of chinook salmon originating from the release of juveniles in 1980 and 1981 and number of females as % of total returns. M - males, F - females, T - total.

Size group	Age at return	Density 1 M	1 F	1 T	2 M	2 F	2 T	3 M	3 F	3 T	Photoperiod* M	Photoperiod* F	Photoperiod* T	Mean of all densities T	Mean of small and large T	Mean of all ponds T
1980																
	1	5	-	5	1	-	1	-	-	-				2		
	2	44	-	44	33	-	33	44	-	44				40.3		
	3	26	20	46	12	7	19	19	4	23				29.3		
	4	-	8	8	5	-	5	7	1	8				7		
Total		75	28	103	51	7	58	70	5	75				78.6		
% females			27.2			12.1			6.7							
1981																
Small	1	-	-	-	-	-	-	-	-	-				-		
	2	34	-	34	23	-	23	13	-	13				23.3		
	3	57	3	60	40	6	46	54	3	57				54.3		
	4	3	11	14	6	23	29	8	19	27				23.3		
Total		94	14	108	69	29	98	75	22	97				100.9		
% females			13.0			29.6			22.7							
Large	1	37	-	37	56	-	56	29	-	29	14	-	14	40.7	20.4	18.8
	2	59	-	59	109	-	109	121	-	121	79	-	79	96.3	59.8	64.6
	3	83	48	131	92	28	120	71	12	83	62	15	77	111.3	82.8	81.4
	4	19	24	43	6	30	36	21	24	45	11	27	38	41.3	32.3	33.7
Total		198	72	270	263	58	321	242	36	278				289.6		
% females			26.7			18.1			13.0							
Mean of total small and large		146.0	43.0	189.0	166.0	43.5	209.5	158.5	29.0	187.5	166	42	208	195.3	195.3	198.5
% females			22.8			20.8			15.5			20.2				

* Fish not differentiated by size

TABLE 16. Fork length (mm) of tagged "jacks" (2 year old) and adult chinook salmon caught in the Canadian commercial fishery. Number of fish measured are in brackets.

Size	Age at return	Density 1 Mean	1 SD	1 N	2 Mean	2 SD	2 N	3 Mean	3 SD	3 N	Average of all densities	Photoperiod Mean	Photoperiod SD	Photoperiod N
1980 release														
	2	449	44	(21)	454	50	(28)	455	49	(21)	453			
	3	643	78	(25)	646	84	(31)	654	91	(34)	648			
	4	786	85	(4)	740	152	(2)	711	102	(4)	746			
1981 release														
Small	2	463	36	(42)	467	30	(26)	464	34	(30)	465			
	3	654	75	(32)	691	74	(19)	655	61	(15)	667			
	4	795	18	(2)	734	107	(5)	773	85	(5)	767			
Large	2	464	26	(54)	469	36	(62)	470	51	(63)	468	469	44	(89)
	3	695	71	42	691	74	(50)	659	61	(46)	682	654	82	(62)
	4	846	75	11	811	100	(10)	845	89	(5)	834	805	67	(15)